panion at Cambridge. Each of these instruments has a long and honorable history. Their work has been very different. Who shall say that one has surpassed the other? We owe to Bond and his son the discovery of an eighth satellite to *Saturn*, of the dusky ring to that planet, the introduction of stellar photography, the invention of the chronograph by which the electric current is employed in the registry of observations, the conduct of several chronometric expeditions between Liverpool and Boston to determine the Transatlantic longitude, and a host of minor discoveries and observations.

Gilliss visited France for study in 1835, before he took up his duties at Washington. The text-books of Bond and Gilliss were the Astronomies of Vince (1797–1808) and of Pearson (1824–29). The younger Bond (George Phillips Bond, born 1825, Harvard College 1844, Director of the Harvard College Observatory 1859–65) and his contemporaries, on the other hand, were firmly grounded in the German methods, then, as now, the most philosophical and thorough.

It was not until 1850, or later, that it was indispensable for an American astronomer to read the German language and to make use of the memoirs of Bessel, Encke and Struve and the text-books of Sawitsch and Brünnow.* This general acquaintance with the German language and methods came nearly a generation later in England. The traditions of Piazzi and Oriani came to America with the Jesuit Fathers of Georgetown College (1844), of whom Secchi and Sestini are the best known.

The dates of the foundation of a few observatories of the United States may be set down here. Those utilized for the observation of the transit of Venus in 1769 were temporary stations merely. The first college observatory was that of Chapel Hill, North Carolina (1831); Williams College followed (1836); Hudson Observatory (Ohio) (1838); the Philadelphia High School (1840); the Dana House Observatory of Harvard College (1840); West Point (1841); the United States Naval Observatory (1844); the Georgetown College Observatory (1844); the Cincinnati Observatory (1845); the new observatory of Harvard College (1846); the private observatory of Dr. Lewis M. Rutherfurd in New York City (1848); the observatory at Ann Arbor (1854); the Dudley Observatory at Albany (1856), and that of Hamilton College (1856).

These dates and the summary history just given will serve to indicate the situation of astronomy in the United States during the first half of the present century. A little attention to the dates will enable the reader to place an individual or an institution on its proper background. It must constantly be kept in mind that the whole country was very young and that public interest in astronomical matters was neither educated nor very general. The data here set down will have a distinct value as a contribution to the history of astronomy in America. The developments of later years have been so amazing that we forget that the first working observatories were founded so late as 1845.

American science is scarcely more than half a century old. The day will soon come—it is now here—when we shall look back with wonder and gratitude to ask who were the men who laid the wide and deep foundations which already maintain so noble an edifice.

EDWARD. S. HOLDEN.

MT. HAMILTON, CAL., April, 1897.

* Dr. Bowditch learned to read German in 1818, at the age of 45.

INHERITANCE OF ACQUIRED CHARACTERISTICS.*

IN approaching the subject of 'The inheritance of acquired characteristics' from

* Paper read at the Boston meeting of The American Society of Naturalists.

the plant side, I believe it may fairly be asserted that the botanist is more favorably provided with subject-matter for investigation than is the zoologist. For thousands of years plants have been grown, selected and disseminated by man, and have thus become his companions, in as true a sense as have the cat, the dog or the horse. For at least a century botanic gardens have existed in all the leading cities of the Old World, for the avowed purpose of promoting scientific information along all lines of plant life. For a couple of centuries or thereby the desire to supply novelties of a useful or decorative kind has stimulated the nurseryman to practice artificial selection, which is just Nature's method at work under high pressure and in the hands of an intelligent conductor. Finally, the botanist, when he pursues his studies afield, deals with organisms that are rooted in definite areas amid definite environments, and from which slow escape by seeding is alone possible.

The present-day student of plant biology thus has four rich sources from which to draw information for the discussion of such topics as that now before us. Unfortunately much valuable knowledge that might have been gleaned is lost to us, since its possible practical application in the future was not recognized in the past. Now the botanist, the horticulturist and the agriculturist are joining hands in an effort to gather, to preserve, and to utilize their stores of information.

Reviewing in thought his different collecting fields, every botanist must be impressed by the fact that certain types of plant are broadly associated with certain surroundings, and particularly is this true of herbaceous plants.

If he attempts to sort out these groups in his mind he will refer most of them to one of the following categories: (1) aquatics, (2) shore or littoral plants, (3) sand or xerophilous plants, (4) shade and humus plants, (5) alpine plants, (6) saprophytic and parasitic plants. Not merely could certain broad principles be laid down for each of these divisions; microscopic study would reveal that in minute details striking similarities reveal themselves in the members of each group. In what follows I do not propose to adhere to the above groupings, but will do so where advisable.

(1) *Aquatic and amphibious plants.* The Buttercup genus (*Ranunculus*) includes about 469 species, some of which are world-wide in distribution. Nearly all are inhabitants of dry or moist soil, but a few like *R. aquatilis* and *R. circinatus* are more or less aquatic. In Europe the former exhibits striking diversity, or heterophylly in the leafage, that is largely determined by the relative depth of water and strength of water current. When growing in ponds or sluggish streams the submerged leaves are dark green, flaccid usually, dissected, and devoid of stomata, but at the ends of the annual shoots and just below the flowers are several floating leaves with expanded, trilobed, light green lamina, that greatly resemble the basal leaves of many land buttercups. Stomata are present over their upper surfaces. In Eastern America the form with submerged leaves alone exists, and even where the plants may be semiterrestrial or completely so, as in the variety *cæspitosus*, the lobed leaves of the European variety do not develop. Such facts cause us to ponder the questions of adaptability and inheritance, but do not in themselves lead us far in our present inquiry.

The Bistort genus (*Polygonum*) is typically a terrestrial one, but includes one species, *P. amphibium*, of highly plastic build. When growing in rather deep water it forms flaccid leaves on long leaf-stalks, and these spring from beside glabrous stipules. On dry land firm leaves with short stalks and hispid stipules appear. These constitute

the varieties *aquaticum* and *terrestre* of some manuals. From F. Hildebrands simple but pretty experiments* we know that plants of the latter variety which have grown for years in dry places will, when submerged a few feet in water, produce shoots that bear in a few weeks the typical floating leaves. While stomata are disposed chiefly over the lower surface of the leaf in the land form, in the aquatic they exist on the upper surface.

Experiments with *Sagittaria*, *Eichornia*, *Potamogeton* and others would demonstrate that in all there is an extreme plasticity of form that permits environmental adaptibility. Comparison with all the species of each genus causes us to inquire whether one of the variation forms has not been acquired through response to stimuli, and has now become a hereditary condition? We need not now stay to answer.

(2) *Shore, littoral or halogen plants.* Abundant along the eastern seaboard is the crimson-flowered *Gerardia purpurea*, that is as variable in habit as it is in the selection of its situation. Within a distance of 100 yards, it may be gathered on a dry exposed sandy bank, and be then about 12 inches high, sparcely branched, faintly red in the leaves, and pale pink in the flowers; or on a flat shady spot in richer soil, when the stem may be 2 feet high, the leaves bright green and elongate, and the flowers pink crimson; or on a rich alluvial mud, when we get a bushy plant 3 feet or more high, that bears long narrow leaves and large showy crimson flowers. But in our botanical manuals *G. maritima* is now given as a true species. It inhabits saline coast-flats, and may even be washed by sea-water without seeming to be injured. A distinctly different plant it looks from the former. From 1 to 8 inches high, it branches little if at all, bears thick succulent reddish-green or glaucous leaves, and one or several small pink flowers.

*Bot. Zeitung, 1870.

On nearly every coast the two can be gathered in close proximity. At Oyster Bay the Shore Railroad separates a drained shore-flat with abundance of *G. purpurea* from an undrained saline swamp that is filled with *G. maritima*, while near Vineyard Haven a drain ditch forms the line of demarcation between the two. Microscopic study of both causes one to ask whether they deserve to be regarded as distinct species. The answer to this may depend wholly on what we call a species, but study of a finely graded set, gathered fully four years ago at Sea Isle, on an inclined bank, would lead me to regard them as common forms that environment has altered. If this be so we should expect that within a longer or shorter period a single individual in its life time, or seminal descendants of such as are gradually 'acclimatized,' will develop macro- and micro-scopic characters similar to those of *Gerardia maritima.* The studies of Lesage* and Russell,† amongst others, yield definite proof. Both have compared, microscopically, individuals of certain species from littoral and inland regions, and the changes undergone by the shore-grown individuals *exactly* correspond with those exhibited by *Gerardia maritima.*

Increase in thickness of the leaf substance chiefly through increase in, and enlargement of, the pallisade cells; an apparent reduction, or possibly wider dispersion, of the chloroplasts; greater lignification of the stem and leaf-bundle elements; enlargement of the vessels; reduction in size of the intercellular spaces, are typical phenomena. The culture experiments of Lesage further verify his field observations. Russell frankly confesses that those grown by him in saline solutions were not so vigorous as those from the Paris basin. Even in this, however, the resemblance to our plant is perfect.

But as Gaston Bonnier has well empha-

*Rev. Gen. de Botanique, Vol. 2, 1890.

†Ann. Sc. Nat. (Bot.), 1895.

sized in his paper on Alpine plants, and as Lesage's work shows, great caution must be exercised in discussing the morphological and physiological relations of species which may grow in close proximity. *Gerardia maritima* is 'at home,' or tries to be, on muddy saline banks, where it is usually protected by the grassy vegetation around. Though we call it a littoral plant, it is modified differently from *Cassia nictitans* or *Yucca filamentosa*, that may be its near neighbors along sand bars. The mention of Yucca can introduce us therefore to that great assemblage that we now call desert or xerophilous plants.

At times met with in full view of the ocean, they are most frequent and attain their most varied development on desert or volcanic areas. Let us linger for a little over *Yucca filamentosa*. Along many miles of the dry sandy ocean front of the Carolinas and Georgia it is a familiar plant. At one season exposed to moist saline breezes, at another to driving winds that hurl the sharp sand particles against it, during a large part of the year exposed to the full glare of hot, sand-reflected sun rays, and never enjoying a superabundance of moisture, though its roots penetrate at least five to six feet below the surface, it still survives and reproduces itself. But it is quite different to the naked eye, and still more so microscopically from the plant that we grow in rich garden soil. Specimens from the ocean beach have a dense, wiry aspect, relatively short, broad, somewhat concave leaves of a glaucous green hue and that end in a hard mucro. Garden plants, on the other hand, that have been cultivated for many years and that may have been themselves reproduced from garden seeds or suckers, bear leaves that are long, narrow and soft leathery in texture, of a dark green hue and with a soft mucro. Seedlings in the neighborhood of each type reproduce their kind.

No matter what the ancestral form may have been or what its natural surroundings, we must here admit acquired characters in one of the types that are reproduced, and our main concern again is to learn whether such changes proceed in the life-time of an individual or can gradually be acquired in either direction by seed selection and propagation. Such papers as those of Duchartre*, Elliot†, Häckel,‡ Lothelier,§ Stenstrom,|| and notably that of Henslow,¶ furnish us with good evidence. For details of Henslow's suggestive paper I would refer you to the original, but Lothelier's studies deserve comment. He varied his experimental methods by making normal air his xerophile environment, and saturated air his new condition.

He summarizes his results alike as to sun and air exposure as follows: (a) stem and leaf substance show a greater amount of indurated tissue in a xerophile state, a reduction of this in a moist atmosphere; (b) the formation of leaf lobes, and, in such as produce them, of spines, is pronounced in a dry atmosphere; (c) the epidermal cuticle is increased, but the epidermal cells are reduced in size, the xylem is connected by a continuous ligneous sheath, and the pericycle is lignified in dry air, while in moist air these features are feebly marked or absent.

It is often stated, and in many cases truly, that the battle in the vegetable world is that of a plant against its neighbors, but with xerophilous plants, that probably cover one-sixth of the earth's surface, the struggle is entirely one between the plant and its physical or animal surroundings. Our native *Opuntia* has had its stem and branches

* Bull. Soc. Bot. de France, 1885.

† Trans. Bot. Soc. Edin., 1891.

‡ Verhand. d. K. K. zool. bot. Gesell. Wien, 1890.

§ Rev. Gen. de Botanique, Vol. 5, 1893.

|| Flora, 1895.

¶ Jour. Linn. Soc. (Botany), Vol. 30, 1894.

shortened, its cuticle thickened, its cells filled with mucilage, its short swollen branches covered with spines, and its now small, succulent, centric leaves short-lived to the extent of a month or six weeks as a gradually perfected resistance to opposing agents. Goebel's experimental results* with the Cacti prove that removal of them to shade and moisture will materially affect their habit.

(4) *Prostrate plants.* In my paper on 'The sensitive movements of some flowering plants under colored screens,'† I described the variations constantly noted in *Cassia nictitans* when grown in the shade on rather moist loam, or in the open on somewhat retentive soil, or when fully exposed to the sun and grown in dry sand. Striking microscopic differences characterize each. This plant is but one of many that show like variations, and not a few of them can be studied as one passes along the quieter streets of our cities. The somewhat loose open growth, ascending branches and spreading leaves of *Euphorbia maculata* when it springs up in a moist shady place differs from those of the humifuse plant with flattly applied leaves that springs up between the bricks of our neglected side walks. Curiously enough, when the latter is attacked by a *Uromyces* the habit of the shade grown plant is assumed. Several grasses, *Portulaca oleracea* and *Mollugo verticillata* are all common humifuse plants when 'baked' in dry places.

(5) *Alpine plants.* Every botanist who has observantly climbed some mountain that rises abruptly from the sea front to an elevation of 3,000–4,000 feet must have been impressed with the change assumed by the vegetation as each successive 1,000 feet is surmounted. On the higher exposed elevations dense, tufted, adpressed plants with short flowering stems and white or bright colored flowers are encountered. These often exhibit close affinity with lowland species of more luxuriant growth and delicate foliage. Are these Alpines then, or the lowland ones, a product of their environment? For the present purpose it will suffice if evidence can be adduced to prove variation transitions from one to the other. Thanks to the beautiful researches of Gaston Bonnier,* supplemented by those of Dufour,† Lazniewski,‡ Leist,§ Wagner|| and Wiesner,¶ we can trace surprising variations within a short period of growth.

Bonnier divided certain plants into three or more parts; he placed one in alcohol, another in a lowland situation, and the remainder on an alpine height. The marvelous transformations wrought in the last are described in the text and faithfully reproduced in his plates. I will content myself with his conclusions. The rhizomes or other underground parts, become lengthened in order the better to store reserve-material, since the aërial period of vegetation is short but intense. The aërial internodes become greatly reduced; the leaves become smaller but considerably thicker; those species that have scattered hairs on low ground have them increased in size; the flowers are reduced in size but brightened in their red and purple colors. Equally marked are the histological changes. Here we have explained the origin of those specific varieties now designated *nana*, *alpina*, etc., which reproduce themselves by seed amid their natural surroundings. How far a plant or group of them when isolated will remain 'true,' or revert, or vary further, we have as yet no experimental data for determining. This much

* Flora, 1895.

† Bot. Central., Vol. 61, 1895.

* Ann. des Sc. Nat. 7th Ser., Vol. 20.

† Ann. des Sc. Nat. 7th Ser., Vol. 5, 1895.

‡ Flora, 1896.

§ Mittheil. der Naturforsch Gesell. von Bern, 1889.

|| Sitz. der Kais. Akad. der Wiss. in Wien, Vol. 2, 1892.

¶ Ber. der Deutsch. Bot. Gesell., Vol. 9, 1891.

can be said, that when apparently fixed species of alpines are transferred to botanic gardens, and cultivated for many years, neither they nor their seed progeny seem to vary appreciably, though it must be granted that a critical comparison has yet to be made. But the comparison which Bonnier has made* between alpines gathered on the Pyrenees, on Jan Mayen and on Spitzbergen, causes us to expect decided differences.

(6) *Parasitic and saprophytic plants.* Volumes might be written in favor of the position that these are alone explicable in terms of their environment. If the Weismannian is in straights over the origin of species amongst the sexless Fungi, more inexplicable seem the sexually perfect flowering parasites. The highly modified and recent order *Scrophulariaceæ* deserves consideration on this continent. To return to the Gerardias that are all more or less pronounced root parasites, such a finely connected series of species as *G. fasciculata*, *G. purpurea*, *G. paupercula* and *G. aphylla* show gradual degradation of the assimilatory organs, as we pass from the Northern to the Southern States. Root, stem and leaf alike all cooperate in the degradation changes. That their floral leaves undergo like reduction suggests a certain rythmic response of the entire organism to altered conditions, and if we pursue our study to those degraded types *Epiphegus*, *Conopholis* and *Orobanche* we see how perfect this response may be. But comparison of Beech Drops (*Epiphegus*) over a pretty wide area of country will afford proof that few plants are more variable, and also that in any one locality the acquired variations are reproduced by this strictly annual species.

(7) *Fasciated plants.* It is now nearly nine years since a botanical friend gathered a wild, fasciated plant of *Polemonium cæruleum* in north Scotland. Its usually slender cylindrical stem was flattened out to a width of about $1\frac{1}{2}$ inches, and from it started a wealth of branches in the axils of the numerous leaves. The plant grew and seeded. Some seeds were retained by him; others were given to the Edinburgh Botanic Garden. From both a considerable proportion of fasciated plants developed. It may at once be objected here that such a teratological state was congenital in the parent plant, but, even granting this for the moment, there seemed strong evidence for its inheritance by the offspring. Long experience in north-central Europe is that fasciation is of rare occurrence. Along our eastern sea-board, especially on sandy soil, with moist substratum, it is frequent. In a single New Jersey meadow 31 specimens of the bulbous Buttercup were gathered by my student party fully four years ago, and prolonged search would have given us more. But an inspection of New Jersey sweet potatoes in the end of September will reveal that from most plants five to eight long shoots radiate outward 20–25 feet. Some are uniform, cylindrical and slender throughout, but half or more of them begin to flatten almost imperceptibly about 5–8 feet from the root region, and are the width of one's hand by the end of a season's growth. They need no further mention, since with us the sweet potato is reproduced by the tuber. But study of such lists as are given in Moquin-Tandon's and Masters' works on plant teratology indicates that plants which, occasionally at least, grow on light soil are those in which such variations occur. De Vries' valuable paper* on the hereditary transmission of fasciation is scientific proof of what every gardener knows to be true. Our now greatly appreciated garden cockscombs, are just monstrous fasciations of the wild *Celosia cristata*, that has a bushy habit, cylindrical stem, numerous leaves, thin

* Rev. gen. de Botanique, Vol. 6, 1894.

*Botanisch Jaarbok, 1894.

branches, and rather loose flower panicles. The wild plant evidently varies readily under cultivation, for several varieties have appeared that are perpetuated true from seed. But no gardener who sows his cockscomb seeds expects all or even the majority to revert to the wild ancestor, though some may more or less perfectly at times. The suggested presence of a fungus that may stimulate to fasciation requires ample confirmation before the view can be accepted.

(7) *Cultivated plants.* Hitherto indications of characters having been acquired have been drawn almost entirely from the wild state, but we must frankly acknowledge that the cases have been few where these characters have been proved to be directly inherited. In cultivated plants we have the strongest possible evidence. At the start let me emphasize the well known fact that the wild type of many of our cultivated plants is unknown. Wheat, oats, barley, corn, the banana, peach, gourd and vegetable marrow are descendants of wild plants that we are still looking for.

Man in his cultural operations has been practicing artificial selection along three lines. He has aimed, first, at a heavy return from individuals, none of which will require special care as individuals, and such we call agricultural crops; second, to obtain a rich fruit supply from individuals that need more detailed attention, and these we commonly call fruit crops; third, to develop a race of showy or handsome decorative plants. The first and second operations have been proceeding for thousands of years, and accordingly we find that the species operated on are those whose wild state we know least about. Be it noted here, however, that artificial selection is very different in its results from the rigorous and impartial selection that works its course in nature. In the latter case those forms survive that are balanced to, or that rise superior to, their environment. In the former man steps in, selects not those types that are hardiest, and in general features fittest for life's battle, but those only which show variations that please him. Such may be the very opposite of desirable in a struggle alongside other plants, or amid such physical conditions as the plant might averagely be exposed to. No wonder then that when man steps out and leaves to their fate the new species that he has evolved, Nature steps in and makes 'short shrift' of them.

Here let me say that many of our most keenly debated biological questions will be largely settled for us in the near future by a diligent study of horticultural and agricultural literature, which, though at times loose, hazy and lacking in exact detail, brings us nearer to the subjects of variation and heredity than does much of our botanical literature. The use that Darwin, Masters, Henslow and Bailey have made of it we all know.

It is impossible in so vast a field to do more than refer to one or two cases. At the World's Fair Horticultural Congress M. de Vilmorin read a paper that in some points settles for us our position in the present debate. Selecting one of the most unlikely of European weeds, the wild Chervil (*Anthriscus sylvestris*), he sowed seeds of it in a selected situation, "in order," says he, "to change its slender and much-forked roots into fleshy, straight and clean roots, say like those of the parsnip. Among the first batch of roots raised from wild seeds a dozen were selected with a tendency in their roots to larger and straighter bodies. Each root was planted separately, and its seed harvested separately. Of the dozen lots obtained, 8 or 9 were discarded at once, and roots were selected only in such lots as exhibited some trace of variation. Again a dozen roots were chosen, a drawing made of each root, which was afterwards planted

separately. For the first ten years the changes were slight, but now they are more and more marked with every generation, and in some of the lots the straight and smooth roots are the most numerous."

Let us briefly trace the history of the Chinese Primrose, which was introduced into English gardens about 1820, but whose natural habitat became known just seven years ago. A variable plant in the wild state, found growing on dry calcareous rocks that are exposed to the broiling sun, it might seem to give little promise of reward for horticultural skill. The first two batches of seedlings reared greatly exceeded expectations, but for years these were propagated chiefly by offshoots. Now garden seeds are entirely used, and few could identify the horticultural prize-taker with the wild specimens collected for the first time a few years ago by Dr. Henry and the Abbe Delavay.

As a somewhat different method of inquiry we have Schindler's comparisons of wheat of the same variety grown in different regions of the world. He finds that the relative amounts of starch and protein vary according to the locality, though samples taken from any one region closely resemble each other.

(9) *Graft plants.* In the literature of gardening the question has often been debated whether the stock and graft reciprocally influence each other. Except in a few rare cases, the negative position has usually been taken, but the experiments of Daniels*, if confirmed and extended, will go far to demonstrate that deep-seated modifications may take place which can be transmitted by seed. When he grafted the cultivated turnip on the wild garlic mustard (*Sisymbrium Alliaria*) the seeds of the turnip produced plants that inclined more to the wild stock. He next reversed the process by growing the wild plant on a cultivated stock. He grew plants of the garlic mustard; some of them he allowed to grow on as control plants; others he grafted on the cultivated cabbage. Seeds were saved and sown from both lots. The former faithfully reproduced the features of the wild parent. Plants reared from the graft garlic seeds were not so tall, the leaves were not so crowded and bore a distinct resemblance to the cabbage, they were of a deeper green color, somewhat plaited, gave a less marked odor of garlic and something of the odor of cabbage. The roots were less woody, the medullary parenchyma was less thickened, the vascular cylinder was reduced but the bast was increased, the bark was more delicate, the chlorophyll more abundant, and the intercellular spaces were reduced as compared with the wild parent.

(10) *Cecidial and domatial plants.* We now approach a subject that is still involved in considerable obscurity, but the bearing of which we believe will greatly aid us in the study of many cell phenomena. Plant galls, or *Cecidia*, in the restricted application of the term, include those outgrowths on leaves or shoots that are caused by insects or mites which undergo development within masses of vegetable tissue, this tissue being produced through excretion of a chemical substance by the hatched grub. Though varying greatly in size, form, consistency and relative abundance, they agree in that the type of tissue built up by the infested plant is diagnostic of the particular species of insect whose egg was deposited. It is not at all uncommon to find eight to ten different galls on one shrub or tree, each rearing a distinct insect species within.

While these have long been known to naturalists, it is only within the past 20 years that attention has been increasingly turned to *Domatia.* These are plant-

* Rev. Gen. de Botanique, 1894; Comptes Rendus, 1892.

growths that attract insects—commonly ants—by offering to them some bait, such as watery liquid or honey. In return the ants commonly act as a body-guard or garrison, and thus protect the entertaining plant from being browsed down by insect enemies. From the investigations of Belt, Beccari, Delpino,* Forbes, Schumman, Treub and others, we now count the number of these as at least 3,000. They fall, however, under two distinct categories: (1) Domatia which are merely extra-floral nectaries, and which may be modified stipules, or may be outgrowths over twigs and leaf surfaces. (2) Domatia in which the entertained insects puncture or excavate some part of the plant. As an outcome, definite holes, cavities or galleries arise, from which plant liquids may escape, or in which the insect-garrison may be appropriately housed. From the researches of Molliard † and Rathay ‡ it appears that transition combinations—and some of them very funny—can be traced from *Cecidia* to both kinds of *Domatia*, but in all we have acquired characters of a remarkable kind. It always appeared to me peculiar and somewhat inexplicable, that neither of these should be, so far as our knowledge went, transmissible by seeds. One may cut open thousands of *Cecidia* in their season—chiefly spring—and always the swelling is found to be tenanted by the inciting cause—the insect. The publication of Lundström's paper § was a welcome one therefore, for, though we could wish for wider verification, his statements seem to be cautiously made. Experimenting with *Rhamnus alaternus* that forms cavernous domatia inhabited by mites, he found that seeds infested by the mites produced seedlings on which the animals propagated rapidly, and at once formed their burrows, while other seeds, selected and cleaned, gave rise to plants that at first showed no signs of domatia, and had no mites, but the later-formed leaves developed the domatia as usual in the axils of the leaf veins. These were smaller and poorer in hairs than the normal growths, but showed no trace of mite.

*Mem. R. Accad. Sc. Ist. Bologna, Vol. 8, 1888.
†Ann. des Sc. Nat., Vol. 1, n. s. 1895.
‡ Sitz. K. K. Zool. Bot. Gesell. Wien, 41, 1891.
§ Nova acta R. S. Sc. Upsal, Vol. 13, 1886.

Equally striking is the history of the well-known Javan plant, *Myrmecodia tuberosa*, and even if we accept with Treub that a small swelling and water canals exist in the unpunctured swelling it seems to me extremely likely that this is acquired and hereditary. My reasons for this opinion are founded on the history of a Bornean pitcher plant, *Nepenthes bicalcarata*, which I have studied from cultivated and from dried imported leaves. First introduced to science and cultivation by Mr. Burbidge, it is now grown in collections and thrives well. At the junction of the tendril with the pitcher and parallel to the latter is an elongated fusiform swelling. About the middle it is pierced, in the wild state, by a neat circular orifice that leads into a cavity resulting from breaking down of soft, loose, water-conducting cells. In the cavity ants reside, and can safely sip the juice that percolates from the liquid-filled pitcher—cavity alongside. I have examined a considerable number of cultivated plants, and on every leaf was a decided swelling filled internally with soft cells. No other species of *Nepenthes* exhibits such an enlargement. Whether cultivated seeds would reproduce the acquired character we are not yet in a position to say.

As regards *Cecidia*, we know that these arise, not immediately after the plant tissues have been punctured by the insect when ovipositing, nor after the egg has been deposited, but only when a larva hatches and exudes some specific irritant. That this irritant should, nevertheless, start in the plant a formation of embryonic tissue that develops in as definite a manner as if it

were a normal growth of the plant, and which yet, as Molliard has pointed out, produces formations different from the normal tissues, is proof that the protoplasmic reaction of somatic cells to definite chemical stimuli is as exact as it is profound. To cite one concrete example from many that Molliard gives, it can be said that *Arabis sagittata* when attacked by an Aphis shows:—

(*a*) An abundance of hairs of special form on all the organs.

(*b*) A coloration due to a pigment-liquid in the epidermal cells.

(*c*) Longer life of the floral organs.

(*d*) Hypertrophy of cells.

(*e*) Transformation of tissue of varied consistency, into a uniform parenchyma.

(*f*) Death of the sexual cells.

In a condensed paper like this it is impossible to touch on such subjects as the origin and transmission of plant colors, of many heterophyllous modifications, of floral numbers and of floral form, nor can we treat of plant hybrids, of which probably 6,000–7,000 are now known.

I would sum up the position by saying that, while in the earlier illustrations used by me evidence was advanced which favored the idea of characters being acquired even in the life-time of an individual and that represented direct environmental adaptation, in later illustrations, such as those furnished by some xerophilous, some domatial, many cultivated and a grafted plant, direct proof exists of acquired characteristics that are hereditarily transmitted by seed. I have not considered it necessary to speak of bud variations and their seminal reproduction, as these have been so fully dwelt on by Darwin and recently by Bailey. The Neo-Darwinian position seems to me superfluous, because it explains nothing on an exact basis of cause and effect. It is easy to say, when variations or evidences of new adaptability appear in a plant, that these are but the expression of previously latent potentialities, or of variations first contracted or assumed by the germ plasm, and that subsequently exhibit themselves in the somatoplasm. Possibly were the eyes of our understanding enlightened we might discover the budding possibilities of an orchid or an oak in an alga, but before accepting such possibilities it may be well to see whether the Lamark-Darwinian principles cannot guide us perfectly and sufficiently far. Here, however, I would suggest, in contradistinction to Wallace, that indefinite variation must be allowed for. Every plant is a structure built up of extremely complex chemical bodies that are being acted on by external and internal stimuli. We can scarcely suppose that new or modified stimuli are always productive of good and good only. Rather should we consider that in each little plant world, as in our larger physical world, volcanic explosions occur that are in one sense a source of safety for the future, but which leave behind beds and streams of debris that may be useless or even destructive. Various of the plant colors, resins, crystals and other frequent compounds may be explicable primarily as side issues that were for the time useless, even though, as in the compounds just named, we find that they now function beneficially in the plant economy.

Every candid examiner of the facts must admit, however, that sudden and several variations often appear in individuals placed side by side with their like that show no change. I do not see that we possess at present a sufficiently exact knowledge of all the possible factors that may start variation to enable us to explain these. Still this should be no deterrent to our accepting the position that generally explains ascertained facts of structure and function.

It now remains for me to say a few words, as a student of plant cytology, on some of the theories that have been advanced to ex-

plain heredity. Darwin's theory of pangenesis has been pushed aside as a cumbrous impossibility, or at least improbability. Even the modified theories of De Vries and others are only tolerated. Weismann's view, that the chromatic substance is the bearer of heredity, has nearly everything to be said in favor of it, if it be accepted that this substance is found in every living cell. But even then, according to the Neo-Darwinian, it has only a very remote connection with the somatic micellæ. Before resuggesting what has seemed to me a good position that explains details of structure, I may be allowed perhaps to become one more of the number of those who have attempted to rehabilitate Darwin's pangenesis hypothesis.

The wandering of his gemmules to and from definite positions has seemed cumbrous and unlikely, but the most fundamental law of plant and animal physiology is circulation, metabolism and ultimate assimilation as the physiological groundwork of life, growth and heredity. On the plant side physiologists have only realized within the past quarter-century how potent and generally present are ferments of diverse composition and action. Thanks to the labors of Green, Chittenden and others, we further know that highly complex nitrogenous compounds are readily converted from solid into liquid form, and can migrate, in an as yet often mysterious manner, to definite centers of nutrition to be again converted into solids. So far as my knowledge of physics and chemistry leads me, there is no obstacle to our admitting that transfers of complex dissolved materials are passing to the protoplasm, and through it to the chromatin of every cell, more or less affecting its micellar structure. It is necessary, therefore, to learn what relation, if any, exists between the chromatic and plasmatic substance of cells.

In such plants as *Spirogyra* and *Dionœa* I regard the chromatic substance as being demonstrably continuous from the nucleolus through the nucleoplasm to the cytoplasm, where connections are made with the chromatic center of each chloroplast. The so-called pyrenoid-centers in *Spirogyra* behave to stains and reagents as does typical chromatin substance, while radiating chromatic threads pass from them to the nuclear chromatin. Furthermore, in *Spirogyra* an extremely fine chromatic thread-work joins the pyrenoid centers in it transversely or obliquely. What the finer invisible terminations of it in the protoplasm may be, we cannot say, but it appears to me that, if physico-chemical laws are not to be thrown aside, it is a necessity of the case that the delicate chromatic endings in the protoplasm are being acted on, and more or less modified according to the nature of the stimuli that travel to them. As a result of this, a slow, steady but appreciable modification will be effected in the reproductive cells which epitomize the molecular structure of the entire organism that produces them.

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CURRENT NOTES ON PHYSIOGRAPHY.

UPLANDS AND VALLEYS OF KANSAS.

THE second volume of the University Geological Survey of Kansas concerns the western part of the State, occupied by Cretaceous and Tertiary formations. The physiographic matter is contributed by Haworth; the geological descriptions by Prosser and Logan. The Tertiary lies unconformably on the broadly eroded Cretaceous. The surface of the latter, north of the Arkansas and west of the paleozoic area, presents three ragged east-facing escarpments of moderate height at the margins of the Dakota sandstone, Benton limestone and Fort Hays limestone, with intervening plains gradually ascending west-